THE KANGAROOS OF YAN YEAN: HISTORY OF A PROBLEM POPULATION

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The catchment of Yan Yean Reservoir is situated on the rural fringe of Melbourne, southeastern Australia, and supports a large population of eastern grey kangaroos (*Macropus giganteus* Shaw). Yan Yean has a mean annual rainfall of 667 mm, which is distributed evenly throughout the year. Eight prominent eucalypt associations occur in the catchment and a total of 310 plant species have been recorded, including a number of threatened taxa as well as invasive weeds. Yan Yean also has a rich vertebrate fauna: 37 mammal, 155 bird, 28 reptile and 18 amphibian species. We have distinguished five habitat zones in the catchment and adjacent farmland, each reflecting a different land-use history. The first human inhabitants, the Wurunjerri-baluk people, were displaced initially by European settlers who began to log, graze and crop the area in the 1830s, and then by construction of the Yan Yean Reservoir in the 1880s. The catchment is closed to the public. Despite the construction of a kangaroo-proof fence, kangaroos have been a source of problems within the catchment and surrounding agricultural land for five decades. The population has been the focus of research into a number of aspects of ecology, particularly population dynamics, demography and parasitology. Despite a variety of techniques used and areas covered, previous surveys of population size have returned estimates ranging between 1770 and 3000 kangaroos, with little evidence of change since the 1960s.

Key words: Yan Yean, eastern grey kangaroo, *Macropus giganteus*, vegetation, vertebrates, Wurunjerri, European settlement, reservoir, kangaroo culling, kangaroo ecology, population survey.

THE eastern grey kangaroo (*Macropus giganteus* Shaw) is common through much of its range on the slopes of the Great Dividing Range and on the semi-arid plains of eastern Australia (Poole 1982). The species occurs in open forest, woodlands and grassland margins, favouring habitats with lateral cover offered by trees or shrubs, together with suitable forage provided by grasses in the ground layer (Caughley 1964; Bell 1973; Hill 1981; Taylor 1985a; Southwell 1987).

Eastern grey kangaroos can become over-abundant in rural settings where patches of woodland or forest are adjacent to improved pastures or crops (Taylor 1984, 1985b; Hill et al. 1988). Farmers often view them as pests that compete with domestic stock for pasture and water, and cause damage to fences and crops (Dempster 1961; Lavery & Kirkpatrick 1985). Over-abundant populations also arise in nature reserves where remnant native forest, woodland or shrubland abut former pasture, as occurs at Rotamah Island in The Lakes National Park, Victoria (Coulson & Raines 1985) and Tidbinbilla Nature Reserve in the Australian Capital Territory (Neave & Tanton 1989).

The kangaroos of Yan Yean Reservoir Catchment illustrate these trends. The catchment forms a mosaic of significant remnants of native woodlands and shrublands, in combination with grassy clearings, forming highly productive habitat for eastern grey kangaroos. This system lies within a matrix of farmland, which is also exploited by the kangaroos. The purpose of this paper is to provide a background for a multi-disciplinary study, which began in 1992, into the ecology and management of the kangaroo population in this valuable research environment.

STUDY AREA

Yan Yean Reservoir Catchment (145°09′E,37°32′S) is situated approximately 37 km northeast of Melbourne, Victoria, Australia (Fig. 1). The catchment

is 2250 ha in area. It is part of the Nillumbik Terrain, a basin to the north and east of Melbourne which contains the Plenty River, Yarra River, Diamond Creek, Merri Creek, Darebin Creek and their tributaries. The catchment of Yan Yean is an area of undulating hills which are an extension of

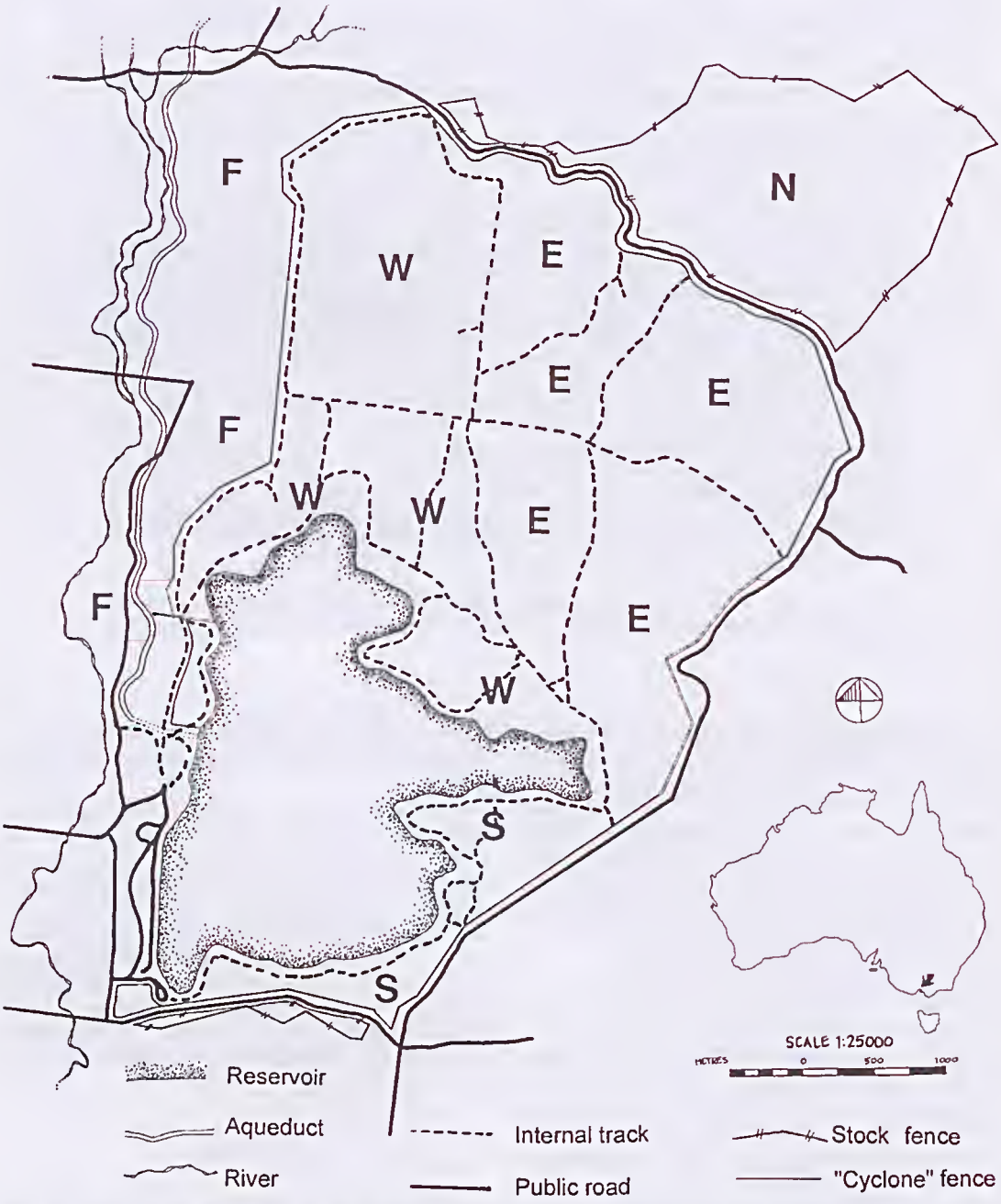

Fig. 1. Map of the study site at Yan Yan Reservoir Catchment, showing the five habitat zones (N = North; S = South; E = East; W = West; F = Farmland). Inset shows the location of Yan Yean in Victoria, Australia.

denuded ridges descending southwards from the Kinglake Plateau. The catchment has the primary role of production and storage of water as part of the supply to the Greater Melbourne area, and is managed by Melbourne Water. The reservoir has a capacity of 30 000 ML, and has a surface area of 560 ha when filled to capacity at 185 m above sea level (MMBW 1989).

Yan Yean is mostly surrounded by farmland, which is being increasingly subdivided for hobby farms and residential blocks. The northeast corner of the catchment abuts the township of Whittlesea (population 2500). Much of the study area is enclosed by a 1.8-m 'Cyclone' chain-mesh security fence topped with three strands of barbed wire. The security fence forms only a partial barrier to kangaroos, which have forced the mesh up from the base and established well-worn runways in many places. Public roads run beside this fence along the northern, eastern and southern boundaries of the catchment, and along part of the western side (Fig. 1). The catchment is closed to the public, and has a network of unsealed roads maintained for management purposes.

Climate

Daily rainfall data have been collected at Yan Yean since September 1855. Yan Yean has a temperate climate, with a mean annual rainfall of 667 mm. The wettest year was 1872, when 1048 mm of rain was recorded; the driest was 1945 when only 370 mm of rain fell. There is little difference in mean monthly precipitation throughout the year (Fig. 2). February has the lowest and most variable rainfall (mean ± s.d. = 45.5 ± 42.5 mm), and is also the hottest month, having mean minimum and maximum temperatures of 16.3°C and 26.8°C respectively (Quin 1989). July is the coolest month (mean minimum of 6.7°C and maximum of 12.9°C), and has the lowest variation in rainfall (51.4 ± 23.1 mm).

Vegetation

The natural vegetation of Yan Yean was comprised of open forest, but previous land-use has modified the present distribution and composition of the flora. A number of prominent eucalypt associations occur in the catchment, where the term association is used to refer to dominance types: red stringybark (*Eucalyptus macrorhyncha*); red stringybark and long-leaf box (*E. macrorhyncha–E. goniocalyx*); red stringybark and candlebark (*E. macrorhyncha–E. rubida*); narrow-leaf peppermint (*E. radiata*); swamp gum (*E. ovata*); swamp gum and white sallee (*E. ovata–E. pauciflora*); Yarra gum (*E. yarraensis*); and river red gum (*E. camaldulensis*) (MMBW 1987). The majority of these associations form open forest on slopes and undulating lowlands, but pure stands of swamp gum and river red gum can be found on the lowest flats, forming open woodland.

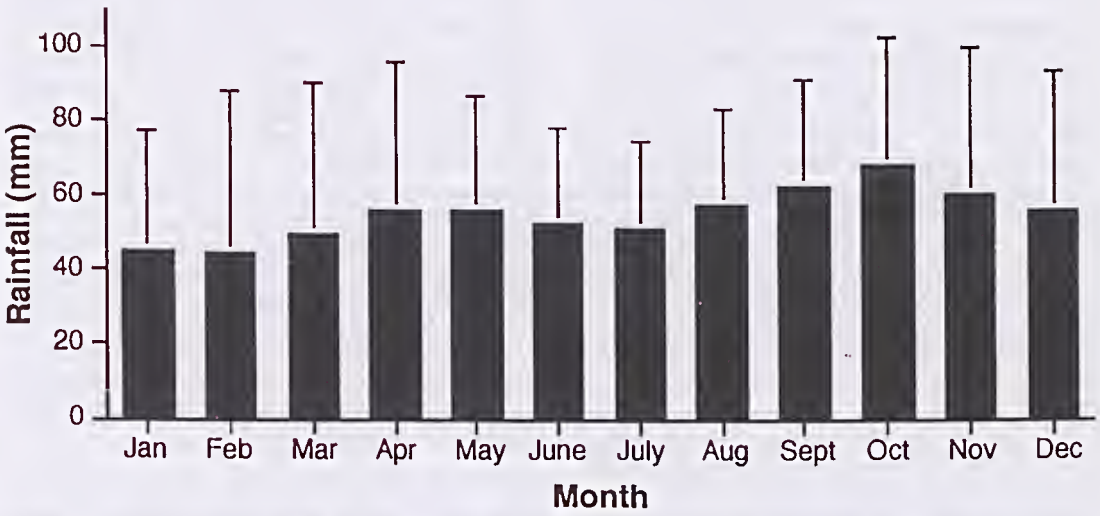

Fig. 2. Mean monthly rainfall for Yan Yean, from records taken since 1855. Error bars show standard deviations.

Of a total of 310 plant species recorded within the catchment, 43 are natives trees and shrubs. The shrub layer, when present, is dominated by wattles (*Acacia implexa*, *A. mearnsii*, *A. melanoxylon* and *A. paradoxa*), cassinias (*Cassinia aculeata*, *C. arcuata* and *C. longifolia*) and cherry ballart (*Exocarpos cupressiformis*). The herbaceous flora is relatively rich (96 monocotyledon and 167 dicotyledon species). The ground flora is predominantly comprised of native grasses such as weeping grass (*Microlaena stipoides*), kangaroo grass (*Themeda triandra*), wallaby grass (*Danthonia* spp.), spear grass (*Stipa* spp.) and tussock grass (*Poa* spp.). The flora of the catchment also includes 66 exotic species, 19 of which are listed as serious invasive weeds in the Melbourne area (Carr et al. 1992). The invasive sweet vernal grass (*Anthoxanthum odoratum*) is particularly widespread. A number of rare and restricted species are present within the catchment, such as narrow-leaf New Holland daisy (*Vittadinia muelleri*) and clover glycine (*Glycine latrobeana*), and there are also examples of restricted remnant communities. Searlett (1983) suggested that the combined impacts of weed invasion and kangaroo grazing were having deleterious effects on the native vegetation of Yan Yean.

Habitat zones

We have distinguished five zones of kangaroo habitat at Yan Yean, each reflecting the effects of differing land use. These zones are bounded by internal tracks, catchment fences and other landmarks (Fig. 1). Three zones, East, West and South, form the major part of the catchment, which is surrounded by the 'Cyclone' security fence. The North Zone has only a standard stock fence and is separated from East Zone by an unsealed public road. The Farmland Zone lies outside the catchment proper and provides additional habitat for kangaroos. It extends westwards from West Zone to the Plenty River and northwards to the outskirts of Whittlesea. The reservoir is also exploited at times by kangaroos, providing drinking water as well as a source of food around the margins when the water level falls. Water is also available in the other zones from permanent dams constructed for fire-fighting or domestic stock, and from several perennial creeks.

North Zone. This 345-ha area has the highest point in the catchment (480 m above sea level), and has steep hills (MMBW 1987). The underlying rocks are Lower Devonian sediments of siltstone with interbedded thin sandstone (Geological Survey of Victoria 1972). The shallow, stony gradational soils generally comprise a hydrophobic gravelly loam A horizon overlying a clayey, stony or gravelly B horizon (Jeffrey 1981; MMBW 1987). Most of the open forest in this zone is dominated by the red stringybark and long-leaf box association. The understorey varies between sparse *Cassinia* spp., *Acacia* spp. and a ground flora of *Poa* spp. on the ridges, to moderately dense undergrowth in the gullies dominated by hop goodenia (*Goodenia ovata*). This zone is relatively undisturbed both by humans and kangaroos.

East Zone. In the higher areas of this 710-ha area (up to 290 m), the underlying rocks are Lower Devonian sediments of siltstone with interbedded thin sandstone; the lower part of the zone is predominantly Silurian sandstone, interbedded with siltstone and shale (Geological Survey of Victoria 1972). The two rock types are bisected by a deposit of river alluvium consisting of sand, silt, clay and minor gravel which follows Dry Creek, an intermittent watercourse, and continues around the margin of the reservoir (Geological Survey of Victoria 1972). The soils are shallow, stony gradational soils in the higher areas, reddish duplex soils on the lower slopes, and yellow gradational soils, with an A horizon described as a clay loam, along the drainage lines (MMBW 1984). This zone consists of two designated botanical Reference Areas and their surrounding Management Zones (MMBW 1987). Yan Yean North Reference Area is representative of the remnant vegetation from low elevation open foothill forests which occur south of the Great Dividing Range, and is dominated by the red stringybark and candlebark open forest association with an understorey of *Cassinia* spp. The vegetation of Yan Yean South Reference Area is comprised of Yarra gum and red stringybark associations on the higher areas and swamp gum and white sallee on the lower areas. The understorey of Yan Yean South Reference Area is dominated by *Cassinia* spp. and *Acacia* spp. on the slopes, with austral bracken (*Pteridium esculentum*) and spiny-headed mat-rush (*Lomandra longifolia*) present in dense patches along Dry Creek. Anthropogenic disturbance of this zone has been relatively minor, as indicated by a reduced number of exotic species. Kangaroo grazing, however, may be playing a significant role in determining the species composition and structure of the understorey.

South Zone. This small (145 ha) area has the lowest relief (185–200 m). The geology consists of Silurian sandstone interbedded with siltstone

and shale, with a recent deposit of river alluvium consisting of sand, silt, clay and minor gravel at its northern edge along the reservoir margin (Geological Survey of Victoria 1972). Reddish duplex soils are replaced by yellow gradational soils with a clay-loam A horizon along the drainage lines and the reservoir margin (Jeffrey 1981; MMBW 1987). The vegetation of South Zone has been influenced by past land-use, and contains a number of naturally regenerating plantations of Monterey pine (*Pinus radiata*), blue gum (*E. globulus* ssp. *globulus*) and sugar gum (*E. cladocalyx*) that have previously been harvested. It also contains a stand of a tree-form silver banksia (*Banksia marginata*), which is unusual for this area, and a high diversity of aquatic species associated with the reservoir margin.

West Zone. The highest points in this 525-ha zone are about 250 m above sea level. The geology of this zone is dominated by Silurian sandstone, which is interbedded with siltstone and shale. A thin band of a mixture of Quaternary deposits of river alluvium consisting of sand, silt, clay and minor gravel, and similarly aged swamp deposits of silt, clay and black mud, follows an unnamed intermittent watercourse that bisects the zone (Geological Survey of Victoria 1972). The soils are similar to those of East Zone. A combination of past land-use and continued kangaroo grazing has had a significant impact on the vegetation in the West Zone. The low-lying flats and surrounding rises are mainly covered by open woodlands of swamp gum and river red gum associations, while stands of drooping sheoke (*Allocasuarina verticillata*) are found on the upper slopes. Cleared areas comprise approximately 20% of this zone and are most likely maintained by constant grazing pressure. Plantations of Monterey pine and sugar gum cover the remaining areas. Introduced species dominate the understorey: bulbil watsonia (*Watsonia meriana* cv. *bulbulifera*), blackberry (*Rubus* spp.) and sweet briar (*Rosa rubiginosa*) are common, along with grasses such as sweet vernal grass and brown-top bent (*Agrostis capillaris*). The zone also has a diverse aquatic flora along the reservoir margin.

Farmland Zone. This zone (about 400 ha) is situated mainly on the floodplain of the Plenty River and, accordingly, the geology of the low-lying areas comprises a mixture of Quaternary deposits of river alluvium consisting of sand, silt, clay and minor gravel and swamp deposits of silt, clay and black mud. These deposits are overlain by yellow gradational soils with a clay-loam A horizon (Jeffrey 1981; MMBW 1987). The higher areas of the zone (up to 240 m) are underlain by the Silurian sandstone, interbedded with siltstone and shale, and the soils are the reddish duplex soils common to the catchment (Jeffrey 1981; MMBW 1987). The managed pasture in this zone is dominated mainly by introduced grasses such as lesser quaking grass (*Briza minor*), squirrel-tail fescue (*Vulpia bromoides*) and brown-top bent. Some native grasses persist, particularly kangaroo grass and wallaby grass, and some small stands of river red gum open woodland remain. Thickets of invasive shrubs such as hawthorn (*Crataegus monogyna*), blackberry and sweet briar are widespread.

Vertebrate fauna

A total of 37 mammal species has been recorded in the *Atlas of Victorian Wildlife* by a 5×5′ grid cell centred on Yan Yean. Of these, 31 are native. Two native mammals are considered rare and are listed as threatened taxa (Schedule 2, *Flora and Fauna Guarantee Act* 1988, Victoria). These are a marsupial carnivore, the brush-tailed phascogale (*Phascogale tapoatafa*), which has been recorded in North Zone, and a riparian-dwelling bat, the large-footed myotis (*Myotis adversus*), which has been recorded in the Farmland Zone. Herbivores other than eastern grey kangaroos are uncommon: the black wallaby (*Wallabia bicolor*) and the introduced European rabbit (*Oryctolagus cuniculus*), occur at low densities in the catchment, and introduced sambar deer (*Cervus unicolor*) and feral pigs (*Sus scrofa*) are observed occasionally (Ecoplan Australia 1995).

Birds have been surveyed at Yan Yean since 1973 on an annual bird count by members of the Bird Observers Club of Australia. The count is part of the 'Challenge Count' run by the club on the first Sunday in December. The area covered at Yan Yean includes the perimeter of the reservoir, the public park below the retaining wall, and parts of South Zone, West Zone and Farmland Zone (G. Hosken, pers. comm.). A total of 155 bird species has been recorded at Yan Yean Catchment since the counts began, and only nine of these are introduced. The native species include several of conservation significance, such as the endangered regent honeyeater (*Xanthomyza phrygia*) and the rare white-bellied sea-eagle (*Haliaeetus leucogaster*). Sea-eagles have frequented Yan Yean since the 1960s, and a breeding pair nesting in a stand of sugar gum in the West Zone has been monitored closely in recent years (F. Muscolino, pers. comm.).

Yan Yean also has a rich herpetofauna. Totals of 28 species of reptiles and 18 species of amphibians have been recorded in the *Atlas of Victorian Wildlife* for the 5×5′ grid cell centred on Yan Yean. All are native species, and only the glossy grass skink (*Pseudemoia rawlinsoni*) is considered to be of conservation significance, because its status is insufficiently known.

HISTORY

Indigenous people

The Wurunjerri-baluk tribes were the first human inhabitants of Yan Yean when the reservoir site was covered mostly by swamp lands (Melbourne Parks & Waterways 1995). The name Yan Yean comes from the Wurunjerri-baluk language, possibly derived from 'Yanyan', a local elder who was a signatory to a treaty that gave control of the Plenty district to white settlers; an alternative meaning is a young unmarried man, in reference to the initiation rituals that boys underwent in the area (Edwards 1978). The last of the aboriginal people left Yan Yean when there was an influx of Europeans brought in to construct the reservoir.

European settlement

Plans for the parish of Yan Yean were completed in 1838 (Jones 1992). By the 1840s, several pastoralists had either purchased land or had leased holdings in the parish (Edwards 1978). Potato and maize crops were grown throughout the 1840s and 1850s, followed by clover, lucerne, rye and other improved pasture species in the 1860s (Edwards 1978). The area was used predominantly for grazing sheep and dairy cattle, and one of the major landholders, John Bear, also cultivated orchards and vineyards covering 400 ha where the West Zone lies today (Griffiths 1992). Timber was also harvested in the catchment until the area was progressively reserved in the 1870s, and part of the East Zone served as the Upper Plenty Farmers' Common from 1874 to 1884 (Payne 1975). In 1884, 50 owners of stock were listed as grazing 402 head of cattle and 77 horses there, and it was estimated that another 100 head of cattle were using the common without a fee (Edwards 1978).

Reservoir construction

The area that is now the Yan Yean reservoir was known as Ryders Swamp by the early European settlers (Griffiths 1992). The Melbourne City surveyor James Blackburn devised the plan for a reservoir at Yan Yean, the first reservoir constructed to supply the rapidly-growing city with water (Edwards 1978). Construction began in 1854, and the first water was supplied in a grand ceremony on 31 December 1857 (Edwards 1978). In 1872 the catchment was proclaimed a permanent reserve for water, managed by the Melbourne and Metropolitan Board of Works (MMBW), and was proclaimed a native game protection area in 1917 (MMBW 1987). From the time of its construction, Yan Yean has been a popular excursion for people from Melbourne (Edwards 1978). At its peak, from 1872–1939, it was the venue for the annual New Year's Day picnic of the 'Friendly Societies', featuring music, merry-go-rounds, highland dancing, and Punch and Judy shows. Today, Parks Victoria manages a small public park near the retaining wall in the south-eastern corner of the catchment (Melbourne Parks & Waterways 1995), which has short walks, views of the reservoir, picnic areas and barbecues, while the catchment itself is managed by Melbourne Water.

Kangaroo management

There has been a long history of complaints about kangaroos from Yan Yean's neighbours, mainly from the Farmland Zone on the western side (Melbourne Water 1982). Most complaints were about crop damage, property damage and stock feed losses. Neighbours claimed that their own destruction permits were insufficient to deal with the kangaroo problem, leading the Fisheries and Game Department to request the MMBW to cull kangaroos within the catchment. Although the MMBW was reluctant to cull on the grounds of risks to water quality and public health, the caretaker of Yan Yean was permitted to shoot a total of almost 600 kangaroos from 1954–1957. No further culling took place, although kangaroos were shot for scientific samples in the early 1960s as part of a research programme (see below). Neighbours also made repeated requests to the MMBW to erect kangaroo-proof fencing around the catchment (Melbourne Water 1982). The MMBW eventually offered to construct fencing if the cost was shared between the landholder and the board (Melbourne Water 1982), and by 1987 the entire catchment (excluding the North Zone) had been fenced with 1.8-m high chain mesh.

Kangaroo ecology

Much of the ecological research on eastern grey kangaroos in Victoria has been conducted at Yan

Yean. In 1961, the Fisheries & Wildlife Department initiated a research programme into the population ecology of the kangaroos at Yan Yean led by Keith Dempster. This work investigated age-specific fecundity and mortality, with particular emphasis on the pronounced die-off of young kangaroos (14–20 months) recorded during the winters of 1961, 1962 and 1963 (Dempster 1964). In part, this work was prompted by the potential risks to public health posed by kangaroo carcasses polluting the reservoir.

Quin (1989) subsequently analysed the population data and skulls that had been collected by the Fisheries & Wildlife Department team between 1962 and 1964. One of the major findings of his analysis were that fecundity was relatively low and seasonally dependent. Births occurred in all months of the year but reached a peak in summer, and although two-thirds of females had reached maturity by their third year, a significant proportion of mature females apparently were not breeding. The second major finding was that mortality was high, seasonally dependent and male-biased. Almost all deaths occurred during winter, and young males in their second year were heavily over-represented. Quin also found that, because the primary sex ratio was at parity, the male-biased juvenile mortality resulted in an adult population that was biased in favour of females.

Arundel et al. (1990) investigated the role of parasitic nematodes in the aetiology of the winter mortality pattern at Yan Yean in 1971 and 1972. They collected juveniles and adults over a year, and found that although adults had few nematodes at any time, juvenile kangaroos often carried heavy burdens, particularly in winter. The nematodes showing a winter peak in juveniles included *Globocephaloides trifidospicularis*, *Rugopharynx australis*, *R. rosemariae*, *Pharyngostrongylus kappa*, *Macropostrongyloides baylisi*, *Paramacropostrongylus torlaiformis* and *Strongyloides* sp. Pathological changes to the gut were evident, and there was a strong inverse relationship between numbers of *Globocephaloides trifidospicularis*, which feeds on blood, and plasma protein, haemoglobin levels, and haematocrit values. The winter peak in the life cycle of these parasitic nematodes thus coincided with the poor forage conditions and cold stresses of winter when juvenile kangaroos were most susceptible to mortality.

Brief studies were conducted in the 1970s by students of Rusden State College (now part of Deakin University). One project (Layton 1975) made some observations of the composition and activity of groups of kangaroos, and determined the age structure of a small sample of pick-up skulls. A second project (Terry 1977) made further observations of kangaroo behaviour and determined the age structure of another small sample of skulls. No further research was conducted on the population until we began our programme in 1992.

Population trends

Previous surveys of the kangaroo population at Yan Yean have been infrequent, and inconsistent in terms of the techniques used and the zones covered. The first census of the population was made in 1961, when the Fisheries & Wildlife Department conducted a drive count of East and West zones (Robertson 1985; Arundel et al. 1990) A line of people traversed half of the study area, then the other half, obtaining counts of 2200–3000 kangaroos from three separate surveys (Table 1). Although drive counts are highly accurate when conducted properly (Southwell 1989), the split procedure used in the 1961 survey may have caused errors due to under-counting if kangaroos evaded the line, and over-counting if kangaroos were counted on the first sweep then moved and were counted again on the second.

Year	Zones	Method	Population size	Source
1961	East and West	Drive count	2200–3000	Dempster (1964) Robertson (1975) Arundel et al. (1990)
1975	East, West and South	Line transect	2935	Morgan (pers. comm.)
1992	East, West and Farmland	Line transect[A]	1770	This study
1995	North, East, West, South and Farmland	Line transect[B]	660	Morgan (1995)
1995	East, West and Farmland	Mark–resight	2109	This study

Table 1. Estimates of the size of the population of eastern grey kangaroos at Yan Yean Reservoir Catchment over four decades. [A]Partial replication of Morgan's earlier transect lines. [B]Survey conducted in two parts, two weeks apart.

No more surveys were conducted until 1975. In June, David Morgan of Melbourne State College (now part of the University of Melbourne), conducted the first survey of the Yan Yean population using rigorous line transect technique (D. Morgan, pers. comm.). He surveyed three transect lines (total length = 8.25 km), two sampling East Zone and West Zone in a roughly east–west direction, and the third sampling South Zone. Morgan stratified the area according to four habitat types (open grassland, open forest, forest/woodland with moderate understorey, forest/woodland with dense understorey). He obtained an estimate of 1.97 ha^{-1}, equivalent to almost 3000 kangaroos (Table 1).

In 1992, we carried out the next survey at Yan Yean, with the aim of replicating the survey conducted by Morgan 17 years earlier. We marked out three transect lines as close as possible to the lines used by Morgan, intending to conduct repeated surveys rather that the single survey in the 1975 study, so we could use temporal rather than spatial replication to increase precision of our estimate. We surveyed the most northerly line 12 times, and the central line 11 times. Vegetation on the third line, in South Zone, had become quite dense and visibility was poor (<10 m), so this line was discontinued after three surveys. In addition, it was apparent that many kangaroos were crossing the security fence between West Zone and the Farmland Zone, so we marked out a fourth transect line (2.2 km long) in the Farmland Zone, added two other habitat types encountered in this zone (open paddock and open woodland), and surveyed the line six times. Our estimate of density (and standard error) for East and West zones together was 1.09 ± 0.39 ha^{-1}, considerably lower than Morgan's estimate of 1.73 ha^{-1} for these zones in 1975. We found that density in the Farmland Zone (1.16 ± 0.19 ha^{-1}) was similar to the other zones, giving an overall estimate of 1770 kangaroos (Table 1).

The next survey was conducted in 1994 by Morgan (1995) as part of an assessment of kangaroo impacts in several reserves managed by Melbourne Water and Melbourne Parks & Waterways (Ecoplan Australia 1995). Teams of observers surveyed 14 transect lines (total length = 32.8 km), half of which ran in a roughly north–south direction, and the others ran roughly east–west. This survey systematically covered the entire catchment for the first time, including North Zone, and covered the Farmland Zone to the west. The population size was estimated to be only 660. We consider this result to be invalid, since it is far lower than both the estimate two years earlier and a second estimate using a different technique a year later (see below). The most likely explanation for this anomalous result was that there was a two-week interval between surveys within the catchment and in the farmland, which allowed the kangaroos to redistribute themselves, thus escaping detection in one or both phases of the survey.

The following year we estimated the size of the kangaroo population using a mark–resighting method, a technique that has not often been used for kangaroos but is commonplace in studies of smaller species (Southwell 1989). We had captured and marked 58 kangaroos with individual combinations of eartags and collars (Coulson 1996). In the course of a study of demographic variables, Penny Fannin recorded numbers of marked and unmarked kangaroos observed from a vehicle transect (length = 16 km) that sampled East, West and Farmland zones (Fannin 1995). She surveyed the transect four times, detecting a mean of 191 kangaroos, of which 2.75% were marked. Using a simple Petersen estimate (Southwell 1989), the size of the population was calculated to be 2109 kangaroos.

Overall, there is little evidence of change in the kangaroo population at Yan Yean. Despite the variety of survey techniques used and the areas surveyed, the estimates (with one exception) have ranged between 1770 and 3000 kangaroos (Table 1), and no long-term trend is evident. It might have been expected that the carrying capacity within the catchment had declined over time as exotic weeds invade and native woody species slowly regenerate on cleared areas. This prediction is supported by the lower density recorded in our 1992 replication of Morgan's survey of East Zone and West Zone in 1975. However, there are no comparable data for the Farmland Zone, so it is impossible to determine whether kangaroos could have compensated for lower carrying capacity in the catchment by making greater use of neighbouring farms. There is an obvious need for a survey regime that is comprehensive, systematic and repeatable, so that population trends can be monitored in the future. We have now established a set of 15 permanent, east–west transect lines (total length = 33.1 km) in the East, West, South and Farmland zones, giving a higher sampling intensity than any previous survey. The lines have been surveyed annually, beginning in the summer of 1996–97.

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